TEMPORAL AND SPATIAL DISTRIBUTION OF INTERIOR ALASKA WHITE-FRONTED GEESE (*ANSER ALBIFRONS FRONTALIS*) DURING FALL MIGRATION AND WINTER STAGING

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ABSTRACT

To address the question if white-fronted geese molting in Interior Alaska could be temporally and spatially delineated from the rest of the mid-continent white-fronted goose population, I (1) determined interannual variation in temporal and spatial distribution of geese from Interior Alaska during fall and winter, (2) contrasted temporal and spatial distribution of Interior Alaska geese with Arctic Slope (Alaska) geese, and (3) contrasted migration timing of Interior Alaska geese with Canadian Arctic geese on fall staging areas in prairie Canada. Migration of Interior Alaska geese occurred synchronously and earlier than migration of Arctic Slope geese between Alaska and fall staging grounds in prairie Canada, but was individually highly variable further south on wintering grounds. Spatial distribution of Interior Alaska geese hardly varied between years on fall staging grounds but varied on wintering grounds. Spatial distribution of Interior Alaska geese and Arctic Slope geese differed mostly on fall staging grounds in prairie Canada. Interior Alaska geese staged longer in the study area in prairie Canada than Canadian arctic geese because they arrived earlier and left at the same time. I conclude that delineation of Interior Alaska white-fronted geese is possible on fall staging grounds in prairie Canada, but not on wintering grounds.

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INTRODUCTION

Mid-continent greater white-fronted geese (*Anser albifrons frontalis)* breed and molt across a vast geographic expanse, extending from the Seward Peninsula in western Alaska to the western shore of northern Hudson Bay (Bellrose 1980, Ely and Dzubin 1994). In Alaska, mid-continent white-fronted geese breed in the Interior, Northwest and in northern portions of the state on the Arctic Slope. In contrast to their tundra-breeding counterparts in northern Alaska and in Canada, white-fronted geese in Interior and Northwest Alaska nest in the transition zone between tundra and boreal forest.

Mid-continent white-fronted geese migrate through the Central and Mississippi Flyways (Bellrose 1980). They accomplish their fall migration mainly in two large steps. During the first step, they fly from their breeding grounds to the Canadian prairies in Alberta and Saskatchewan where they stage for up to several weeks, before moving south through the Great Plains to their wintering grounds in Louisiana, Texas, and Mexico (Ely and Dzubin 1994). Throughout their range, these geese are an important resource for subsistence and sport hunters (Webb 1999, Georgette 2000, Wong et al. 2000, Sharp and Moser 2001).

Monitoring abundance of white-fronted geese is part of the inventory plan of the Koyukuk/Nowitna National Wildlife Refuge in Interior Alaska (US Fish and Wildlife Service, 1992). In the mid-1990's, standardized index surveys conducted by boat or canoe on the Koyukuk National Wildlife Refuge (NWR) first indicated a decline in abundance of white-fronted geese (Spindler et al. 1999). This trend in Interior and Northwest Alaska was corroborated by data from the Continental Waterfowl Breeding

Population Survey, which has been conducted in Alaska since 1957 by the U. S. Fish and Wildlife Service (USFWS) Division of Migratory Bird Management (Hodges et al. 1996, Conant and Groves 2004, Spindler et al. 1999). Because this local decline occurred during a period when the overall mid-continent white-fronted goose population was estimated to be stable or increasing (Trost et al. 1990, Nieman et al. 2003), biologists sought to improve estimates of abundance and to assess production and survival of Interior-Northwest Alaska white-fronted geese.

In 1994, staff at Koyukuk NWR began to develop an intensive aerial survey timed to occur during the peak of molt, when white-fronted goose sightability in the boreal forest is highest. This survey was later expanded to include Innoko NWR and Selawik NWR (2000), Kanuti NWR (2001), and Noatak Preserve and the northern Seward Peninsula (2003). At Koyukuk NWR, abundance of molting white-fronted geese decreased steadily from 1994 to 2001, raising concerns of local extirpation.

Changes in population trends are caused by changes in immigration, emigration, production, or survival. In 1994, staff at Koyukuk Refuge initiated a VHF telemetry study to gain information regarding production of Interior white-fronted geese. Based on results from this study, Spindler and Hans (2005) believed production of Interior Alaska white-fronted geese to be adequate to sustain growth of this segment of the mid-continent population.

Concerns over a decline in numbers of Interior Alaska white-fronted geese further prompted an extensive analysis of legband recoveries and neckcollar resighting data (Ely and Schmutz, 1999). Ely and Schmutz (1999) found that Interior Alaska white-fronted

geese differed distinctively in their migration ecology from white-fronted geese from other breeding grounds: Interior Alaska white-fronted geese migrated earlier during fall and spring. They were more likely to winter farther south, in Mexico, and within Mexico, they were found more often in the central Highlands. Further, Interior Alaska white-fronted geese had a lower annual survival rate than white-fronted geese from other segments of the mid-continent population (Ely and Schmutz, 1999).

Mid-continent white-fronted geese are currently managed as a single population. The mid-continent white-fronted goose management plan (Sullivan, 1998) states that "temporal and spatial tailoring of regulations may be used to address concerns about biologically identifiable population segments than can be effectively managed as separate units". The differences in nesting ecology, distribution, migration ecology and survival between Interior Alaska white-fronted geese and white-fronted geese from other breeding grounds as described by Ely and Schmutz (1999), in combination with the concerns regarding a decline in numbers of these geese, suggest that different management strategies may be appropriate for Interior Alaska white-fronted geese. However, targeted management actions require specific knowledge of the spatial and temporal distribution of the population segment to be managed, including the extent of overlap with other population segments.

For this thesis I have investigated if Interior Alaska white-fronted geese can be spatially and temporally delineated from mid-continent white-fronted geese from other breeding grounds to an extent which would allow for differential management. I outlined three specific objectives. In the first chapter I used data from satellite telemetry to (1)

determine interannual variation in temporal and spatial distribution of Interior-Northwest Alaska white-fronted geese in their fall and winter range, and (2) contrast temporal and spatial distribution of white-fronted geese from Interior-Northwest Alaska with white-fronted geese from the Arctic Slope (Alaska) segment of the mid-continent white-fronted goose population. In the second chapter I addressed immigration and emigration processes in one specific area during fall migration. I used mark-recapture methods to (3) contrast migration timing of Interior Alaska white-fronted geese with white-fronted geese molting in arctic Canada on fall staging areas in the Canadian prairies. Mid-continent white-fronted geese from different breeding grounds aggregate and commingle more during their fall migration while staging in Alberta and Saskatchewan than at any other time of their annual cycle. White-fronted geese are also heavily hunted while staging during fall migration (Sharp and Moser, 2001). I sought to investigate differences in fall residence time in the Canadian prairies between white-fronted geese of Interior Alaska and white-fronted geese molting in arctic Canada. This was based on the possibility that low annual survival rates of Interior-Northwest Alaska white-fronted geese could be caused by higher hunting mortality as consequence of longer fall residence time in the Canadian prairies. For that purpose I gathered neckcollar resighting data and examined at what rates white-fronted geese from different breeding grounds arrive in the Canadian prairies and at what rates they depart. In both chapters I have included management recommendations which would likely benefit birds from Interior Alaska and potentially result in an increased annual survival rate.

CHAPTER 1. DISTRIBUTION OF ALASKA MID-CONTINENT WHITE-FRONTED GEESE (*ANSER ALBIFRONS FRONTALIS*) DURING FALL AND WINTER[1]

Abstract

Greater white-fronted geese (*Anser albifrons frontalis*) breeding in Interior-Northwest Alaska are a segment of the mid-continent population of white-fronted geese. In recent years, they have survived at a lower rate than white-fronted geese from other segments of the mid-continent goose population (Ely and Schmutz, 1999), which may have contributed to a local decline in their numbers. If this segment is to be managed separately as a result of concerns over its decline, information regarding its spatial and temporal delineation and potential overlap with other population segments is necessary. In this study, we used satellite telemetry to determine interannual variation in temporal and spatial distribution of Interior-Northwest Alaska white-fronted geese in their fall and winter range, and to assess their temporal and spatial overlap with white-fronted geese molting on the Arctic Slope of Alaska. From 2001 to 2003, we implanted satellite transmitters in 51 white-fronted geese in Interior-Northwest Alaska and on the Arctic Slope. Migration timing did not differ among years for the Interior-Northwest Alaska birds. Spatial distribution was relatively consistent among years on fall staging grounds in Alberta and Saskatchewan, but varied considerably south of Canada during late fall and on winter staging grounds. The spatial and temporal distinction between geese from Interior-Northwest Alaska and geese from the Arctic Slope, Alaska, was most

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pronounced in Alberta and Saskatchewan. During the first part of the fall migration, differences in migration timing were significant ($p<0.023$) between white-fronted geese from Interior-Northwest Alaska and white-fronted geese from the Arctic Slope, while south of Canada migration timing did not vary between these two population segments. Overlap in spatial distribution between white-fronted geese from Interior-Northwest Alaska and white-fronted geese from the Arctic Slope was small in Alberta and Saskatchewan. This indicates that areas in Alberta and Saskatchewan may provide an opportunity for differential management of various population segments within the mid-continent population of white-fronted geese.

Keywords: Alaska, *Anser albifrons frontalis*, distribution, migration, satellite telemetry, timing, white-fronted goose

INTRODUCTION

The mid-continent population of greater white-fronted geese (*Anser albifrons frontalis*) nests and molts across a wide geographic range, extending from the Seward Peninsula in western Alaska to the western shore of northern Hudson Bay (Bellrose 1980, Ely and Dzubin 1994). Greater white-fronted geese that breed in Interior-Northwest Alaska can be distinguished from other segments of the mid-continent population in several ways; they nest mainly in the boreal forest (Spindler et al. 1999), and they nest and migrate earlier in spring and fall. On the wintering grounds geese from Interior-Northwest Alaska have a more southern and western distribution, which extends into the Mexican highlands (Ely and Schmutz 1999, Ochoa Barraza et al. 2000). Numbers of white-fronted geese breeding in Interior-Northwest Alaska have been difficult to

document because of their scattered distribution and because of their secretive nesting behavior within the boreal forest habitat. Spindler et al. (1999) suggested that white-fronted geese from Interior Alaska may comprise approximately ten percent of the mid-continent white-fronted goose population.

In the 1990's, monitoring efforts conducted by Spindler et al. (1999) suggested that numbers of white-fronted geese in some parts of Interior-Northwest Alaska were declining. These concerns gave rise to a study of nesting ecology of white-fronted geese in Interior Alaska (Spindler and Hans, 2005) and to an extensive analysis of legband recoveries and neckcollar resightings (Ely and Schmutz 1999, Hines et al., 2002). While production of white-fronted geese in Interior Alaska is believed to be adequate to sustain growth in this segment of the mid-continent population (Spindler and Hans, 2005), banding analysis showed that these geese had a lower annual survival rate than white-fronted geese from other segments of the mid-continent population (Ely and Schmutz 1999, Hines et al., 2002).

Currently, mid-continent white-fronted geese are managed as a single population. However, given the differences in survival between white-fronted geese from Interior-Northwest Alaska and white-fronted geese from other segments of the mid-continent population, differential management strategies may be appropriate. Targeted management actions require specific knowledge of the spatial and temporal distribution of the population segment to be managed, including the extent of overlap with other population segments. Current knowledge of spatial and temporal distribution of white-fronted geese from Interior-Northwest Alaska during migration is based on legband recoveries and

neckcollar resightings. Legband recoveries rely on hunter recovery and reporting. Hunter recovery varies with hunting pressure, which likely varies across the range of the species, leading to an over-representation of regions where white-fronted geese are more heavily hunted. Reporting rates also vary across the range of the species; Ely and Schmutz (1999) have shown that reporting rates for white-fronted geese have been lower in Alaska and Mexico than in the remainder of their range. Differences in non-hunting mortality could bias assessments of spatial distribution in a similar way. Data from neckcollar resightings depend on an extensive network of observers and are skewed towards areas where geese occur in large numbers and are easily accessible.

In this study, we have employed satellite telemetry as a means of semi-continuous tracking of individual geese with the following objectives: (1) determine interannual variation in temporal and spatial distribution of Interior-Northwest Alaska white-fronted geese in their fall and winter range, and (2) compare temporal and spatial distribution of white-fronted geese from Interior-Northwest Alaska with white-fronted geese from the Alaskan Arctic Slope segment of the midcontinent white-fronted goose population.

STUDY AREA

Capture locations

White-fronted geese to be implanted with transmitters were captured on their molting grounds in several regions in Interior-Northwest Alaska during 2001-2003 (hereafter Interior Alaska or INA) and on the Arctic Slope (AS) during 2003. In Interior Alaska these regions included Koyukuk National Wildlife Refuge (NWR), Innoko NWR, Kanuti NWR, Selawik NWR, and Noatak National Preserve. Koyukuk NWR, Innoko NWR, and

Kanuti NWR consist of a vast mosaic of boreal forest intermixed with numerous rivers, sloughs and lakes. The Selawik NWR and the Noatak National Preserve are in a transition zone between boreal forest and tundra.

The Arctic Slope of Alaska is separated from Interior and Northwest Alaska by the Brooks Range and extends to the Arctic Ocean. It lies beyond the arctic treeline and consists of mountains and foothills near the Brooks Range and plains near the coast. Capture sites included areas around Deadhorse and Teshekpuk Lake, which constitute two of the main molting areas for geese in the Arctic Costal Plain (Derksen et al., 1982). Estimated numbers of white-fronted geese breeding and molting on the Arctic Slope in Alaska have varied during the past two decades, but indicate population growth rather than decline (Mallek et al., 2004). AS white-fronted geese are thought to be more similar in migratory characteristics to white-fronted geese from the western Canadian arctic than to INA geese (Ely and Schmutz, 1999). Exchange between the two Alaskan population segments is believed to be small based on legband recaptures (Ely and Schmutz, 1999). If the results of this study indicate spatial and temporal differences in distribution during fall and winter between two population segments of such close geographic proximity, it is conceivable that differences also exist on a larger scale.

Fall and winter staging grounds

Spatial and temporal analysis of location data was divided into two parts according to the fall migration of mid-continent white-fronted geese, which is accomplished mainly in two segments (Ely and Dzubin, 1994). During the first segment, geese fly to the prairies in Alberta and Saskatchewan where they stage for extended periods of time. The prairies

in Alberta and Saskatchewan are unique to the migratory path of mid-continent greater white-fronted geese as they constitute a staging area where all mid-continent white-fronted geese from different breeding grounds congregate during their fall migration. For that reason, the management plan for mid-continent white-fronted geese identifies the annual fall staging surveys conducted in the Canadian prairies as the primary tool to assess range-wide population status (Sullivan, 1998).

During the second segment, mid-continent white-fronted geese move south through the Great Plains to their wintering grounds in Louisiana, Texas, and Mexico (Ely and Dzubin, 1994). During the fall and winter months, white-fronted geese feed largely on waste grains in agricultural crops and use a wide variety of waterbody types for roosting (Ely and Dzubin 1994, Ochoa Barraza et al. 2000, Yepez Rincon 2004). White-fronted geese are hunted throughout most of their fall and winter range.

METHODS

Capture and surgery

White-fronted geese were captured and implanted with satellite telemetry transmitters during 2001-2003. During their molt between 8 July and 17 July, flocks of flightless geese roosting on waterbodies were herded to shore and into capture nets by float planes with the assistance of people on foot (Lobpries, 1980). We selected geese to be implanted based on a high body weight and a general appearance of good health. With three exceptions, implanted geese were female. All white-fronted geese chosen were marked with a U.S. Fish and Wildlife Service metal leg band on one leg and a metal reward band on the other leg. INA geese were implanted with transmitters during all three years, AS

geese received transmitters in 2003 only. Forty-two transmitters were allocated to the different regions within Interior Alaska, roughly proportional to the number of geese thought to molt in each region (Spindler et al. 1999). On the Arctic Slope we implanted nine transmitters into white-fronted geese at two locations (Fig. 1. 1).

Geese selected for satellite telemetry were transported in small plastic kennels by airplane to a surgery facility which was at a distance of approximately 50 km. A veterinarian trained in the implantation procedure performed the surgeries assisted by a trained individual or a veterinary technician. The technique followed Korschgen (1996) and Mulcahy and Esler (1999) with some modifications (Cheryl Scott DVM, pers. comm.). Surgery lasted approximately one hour per bird. If a bird was held longer than six hours before surgery, it was given fluids orally prior to surgery and subcutaneous fluids at the end of surgery. After the surgery, geese were placed in small covered plastic kennels to recover. When they were fully alert with control over movements of head and neck they were returned to their capture site and released. Processing time from capture to release (approximately seven to 16 hrs) varied based on the number of birds implanted from one capture event (maximum of five birds), the time of day, and weather conditions.

Transmitter specifications and duty cycles

The battery powered PTT-100 (Platform Transmitter Terminals - Microwave Telemetry, Inc. Columbia, Maryland), weighed 38 g and averaged 1.6% of the body weight of implanted geese. We chose implants rather than neckcollar or other attachments because neckcollars significantly lower survival of white-fronted geese

(Alisauskas and Lindberg, 2002) while abdominally implanted transmitters have few detrimental effects on geese (Hupp et al., 2006 *in press*).

The PTTs provided approximately 650 hrs of transmitting time and were programmed to emit signals intermittently to prolong battery life. PTTs were programmed with different duty cycles to conform to anticipated movements of geese. Duty cycles were similar between 2001 and 2002 and focused on spatial and temporal characteristics of migration (eight hours on – 53/55 hours off during migration in fall, eight hours on – 91 hours off during wintering). In 2003, duty cycles were changed to less intense transmission during late fall and winter to extend battery life into the following breeding season (seven hours on – 55 hours off during the beginning of migration in fall; seven hours on – 162 hours off during the end of migration in fall and wintering).

Analysis

ARGOS data filtering --Transmitter signals were received by the ARGOS satellite system which is located on polar-orbiting weather satellites from the National Oceanic and Atmospheric Administration (NOAA). ARGOS provided a measure of position accuracy with each location based on the number of PTT messages received. Position accuracy was given in seven location classes (LC): 3 (accuracy <150 m), 2 (150-349 m), 1 (350-1000 m), 0 (> 1000 m), the remaining three A, B, and Z indicated that no estimation of position accuracy could be made (ARGOS 1996). Location classes A and B have been shown to be on average within 7.5 km and 35.4 km, respectively, of the true location (Britten et al. 1999). All locations received were filtered using a custom algorithm (Dave Douglas, USGS Juneau, unpubl.). The algorithm retained locations

classified one or higher by ARGOS and, to maximize information gained, selectively retained locations from the remaining ARGOS classes based on the distance to previously and subsequently chosen locations, the rate of movement and the angle of the path along which the movement occurred in relation to previously and subsequently chosen locations. In other words, we eliminated locations that seemed biologically implausible given the distance and direction from previous and subsequent locations. Using the algorithm, we then determined the best location for each seven to eight hour-period of transmission. In a few cases we made manual adjustments to the filtered data. Eighty-four percent of locations used for analysis were attributed to location classes one to three. Five INA geese were censored from the analysis, four of them died while still on their molting grounds, and the transmitter in the other goose failed shortly after deployment.

Temporal distribution – We examined variation in arrival and departure dates among years for INA geese and between INA geese and AS geese. These differences were only investigated in portions common to the migration route of all geese - in Alaska, Alberta, and Saskatchewan - and at the southernmost location we received for each goose. Because transmitters were not active every day, the exact dates of departure from, or arrival at, an area were in most cases unknown. Therefore, we denote date of arrival as the day of the first location in a given area and date of departure as the day of the last location in a given area. We used the Kolmogorov-Smirnov test statistic for two independent samples at an alpha level of 0.05 to test for differences in arrival and departure dates (Zar, 1999), and controlled for multiple comparisons by correcting alpha levels according to the Bonferroni method (Zar, 1999). Because interannual differences

were not significant for INA geese (see Results), the data were pooled across years for comparison with AS geese. Statistical analyses were performed using SPSS software (SPSS, 1997).

Spatial distribution – We examined spatial distribution during two phases of migration: (1) on fall staging grounds in Alberta and Saskatchewan, and (2) south of Canada during winter. We used data up to 11 February to define winter distribution because most geese migrating as far south as Mexico had initiated northward movement by then. Further, by 11 February, hunting has ended in most states, and we were mainly interested in the distribution of geese while they are hunted. We used fixed kernel analysis (Worton, 1989) based on least squares cross validation (Silverman, 1986) to delineate areas of use by white-fronted geese. We considered the 95% probability polygon to represent an estimate of total distribution, and the 50% probability polygon to represent core use areas. Locations and polygons were plotted using ARC/INFO v. 9.0 and Arc View v. 3.1 (Environmental Systems Research Institute, Inc., 2002), and kernel utilization distributions were calculated using the Animal Movement extension in Arc View (Hooge and Eichenlaub, 1997). We compared spatial distribution among years and between population segments by calculating overlap between polygons. Total areas were obtained by merging the polygons considered and calculating the total area of the resulting merged polygon. Overlap was then determined by calculating the percentage of area covered by all polygons considered with the merged polygon. Due to the differences in deployment locations within Interior-Northwest Alaska and to the annual spatial variability in the INA population segment (see Results), we used locations obtained from

transmitters deployed in 2003 only for spatial comparisons between INA geese and AS geese.

RESULTS

Temporal distribution

Interannual variation – Arrival and departure dates INA white-fronted geese did not vary significantly among years (smallest p-value of three [the three possible pairs of years] tests: departure from Alaska $p=0.266$, arrival in Alberta/Saskatchewan $p=0.141$, departure from Alberta/Saskatchewan $p=0.077$, arrival at southernmost location $p=0.340$). Within years, an increase in associated uncertainty with time (Table 1. 1) indicated higher individual variability in arrival and departure dates as geese progressed south. On average, INA geese departed Alaska during the third week of August, and arrived in Alberta and Saskatchewan between three and four days later (Table 1. 1). They departed from Alberta and Saskatchewan after approximately six to eight weeks, in the second half of October. They reached their southernmost locations approximately eight to 13 weeks after leaving Canada, between mid-December and mid-January.

Comparison with Arctic Slope – Because differences in temporal distribution among years were not significant for INA geese, data were pooled across years for comparison with AS geese. AS geese left Alaska approximately one week after INA geese (Table 1. 1, $p<0.001$). They arrived in Alberta and Saskatchewan almost two weeks later than INA geese ($p<0.001$) and left there about one week later ($p=0.023$). Arrival at southernmost locations was not significantly different between INA geese and AS geese ($p=0.584$).

Spatial distribution

Interannual variation -- In Alberta and Saskatchewan, the 95% polygons of INA geese occurred in two to three disconnected areas (Fig. 1. 2), covering regions in the Peace River Country in north central Alberta, between Edmonton and Calgary in east central Alberta, and southwest of Saskatoon in Saskatchewan. Overlap of 95% polygons varied among years but always was ≥ 30% (Table 1. 2). Use of the Peace River Country showed the largest changes in size between years, the area covered was over 90% larger in 2003 than in 2001. The two disconnected core areas were located in nearly identical regions among years, one in east central Alberta and one in southwest Saskatchewan along the South Saskatchewan River. However, they varied in size among years which resulted in less than 20% of core area common to all three years.

During the remainder of the fall migration and during winter, spatial distribution of INA geese was widespread and variable between years (Fig. 1.3). The 95% polygons occurred in two to four disconnected areas. Overlap was similar to Alberta and Saskatchewan, approximately 30% (Table 1. 2). Areas of overlap were in central Kansas, coastal Texas, and Tamaulipas and Nuevo Leon in Mexico. Areas in the Mexican highlands and in northern Texas were part of the distribution in 2001 and 2002 but not 2003. Conversely, areas in Nebraska and South Dakota were part of the distribution in 2003, but not so in 2001 and 2002. The 50% contour varied considerably in distribution between years, resulting in no overlap across all years combined. Contrary to Alberta and Saskatchewan where variations in percentage of overlap were mainly due to changes in

size of polygons, the degree of overlap south of Canada was largely influenced by positional shifts of polygons.

Comparison with Arctic Slope – In Alberta and Saskatchewan, the 95% contour of AS geese outlined three disconnected areas (Fig. 1. 2). Overlap between these areas and the 95% probability distribution of INA geese implanted in 2003 amounted to almost 30% (Table 1. 2); however, overlap of core areas was less than one percent. During the remainder of the fall migration and during winter, percent overlap between INA geese and AS geese was larger than in Alberta and Saskatchewan (Table 1. 2), with main areas of overlap in Kansas and coastal Texas (Fig. 1. 3).

DISCUSSION

Interannual variation

Variations in timing of migration by geese have been related to weather conditions such as temperature, wind, and precipitation (Blokpoel and Richardson 1978, Flickinger 1981, Wege and Raveling, 1983). Spatially, however, one could hypothesize that it would be beneficial to return to staging areas because of familiarity with the distribution of food resources, roost sites, cover, and predators (Diefenbach et al. 1988, Robertson and Cooke, 1999). Indeed, some geese are thought to be faithful to their fall staging (Fox et al., 2002) and wintering grounds (Wilson et al. 1991, Reed et al. 1998). However, comparisons between studies are difficult because philopatry is assessed at different spatial scales (Robertson and Cooke, 1999). If we assume, that in every year of our study, geese which received a transmitter were representative of the INA white-fronted goose population, our

results showed the opposite: there were no temporal differences between years but a large degree of spatial variation during the second half of migration and during wintering.

The variability in spatial distribution among years displayed in our results may be related to sample composition and sample size. During our study, we implanted transmitters into white-fronted geese from different regions within Interior-Northwest Alaska to obtain a representative sample. However, we were unable to maintain consistency in the proportion of samples from each region in which we implanted geese, which may have had a confounding effect if there is real variation among sampling regions within Interior Alaska as to where and when geese migrate. Ely and Schmutz (1999) showed that the longitude of the wintering grounds of mid-continent white-fronted geese was correlated with the longitude of breeding grounds; a concern is whether such a correlation exists on a smaller scale among these sampling sites. However, the limited sample sizes in our study did not allow us to explore this potential correlation. Variation due to a non-random and small sample is likely the cause for the lack of geese from the Mexican Highlands in 2003. In 2003, we did not capture geese for satellite telemetry at Koyukuk or Innoko NWR. Perhaps geese from these areas have a greater affinity for the Mexican highlands. The Mexican Highlands have been known winter staging grounds for INA white-fronted geese. Ochoa Barraza et al. (2005) found that >90% of neckcollar observations and band recoveries collected in the Mexican Highlands were from white-fronted geese from Interior Alaska, and Ely and Schmutz (1999) showed that INA geese are more likely to stage in the Mexican Highlands than mid-continent white-fronted geese from other breeding grounds.

It may be possible, on the other hand, that white-fronted geese, while often showing high site fidelity to their breeding grounds (Ely and Scribner, 1994, Spindler and Hans 2005), are more flexible in the choice of their wintering grounds by adjusting their migration according to external factors such as weather conditions, as has been shown in a number of other waterfowl species, for example in wintering Canada geese (Hestbeck et al., 1991). According to Ochoa Barraza (2000), a decade-long drought in the Mexican highlands has reduced the size and availability of waterbodies used by geese. A weather related shift in distribution of geese has also been observed by local residents in Alberta and Saskatchewan. White-fronted geese have apparently staged more often in Alberta in recent years as a consequence of a drought in Saskatchewan which eliminated shallow lakes and ponds that geese previously used. Incidental evidence from this study shows that a small fraction of individual white-fronted geese occasionally change wintering grounds by a distance of several hundred kilometers between years.

The relative importance of central Kansas during fall and winter was somewhat surprising. Kansas has been described as an important staging ground for white-fronted geese (Ely and Dzubin, 1994), but not as a major wintering ground. This may be a relatively recent development, which may support the contention mentioned above that geese can be flexible in the choice of their wintering grounds. Annual counts conducted in Kansas bimonthly from September through March have shown a dramatic increase in white-fronted geese during the past two decades, with increasing numbers of geese present throughout the winter in the last few years (Marvin Kraft, Kansas Waterfowl Program Coordinator, pers. comm.). Reasons for this increase are not known. They are

unlikely related to hunting pressure because nearly all areas in Kansas important for geese have been hunted intensely.

Spatial distribution in Alberta and Saskatchewan was relatively consistent, areas of use changed mainly in size. The core area in southwest Saskatchewan was comparably smaller in 2001 than in 2002, which may have been due to differences in the water level of the South Saskatchewan River. In 2001, the river was very low, leaving some of the traditional roosting areas dry, while water levels were normal in 2002.

Comparison with white-fronted geese from the Arctic Slope

INA white-fronted geese were earlier than AS white-fronted geese in their migration timing up to and from staging areas in Alberta and Saskatchewan. This confirms results from banding analysis by Ely and Schmutz (1999) and can be explained with the earlier phenology of the boreal forest compared to the arctic tundra. On the one hand, geese in the boreal forest are able to initiate and complete breeding and raising young comparably early. On the other hand, grazing lawns and draw-down lakes in the boreal forest are flooded by mid-August and the vegetation is senescent which may force geese to depart their breeding and molting areas earlier than geese breeding in the arctic tundra. Differences in arrival times at southernmost locations between INA geese and AS geese were not significant, which was probably due to the high degree of variability within distributions in combination with the small sample size of geese from the Arctic Slope. Geese implanted with satellite transmitters were exclusively failed or non-breeders, plus we selected large and healthy geese which were likely to withstand the stress of the surgery. This could have influenced our results, particularly migration timing. It is quite

likely that failed and non-breeders start their fall migration earlier than breeders accompanied by young of the year. This may have biased our estimates early, particularly estimates of immigration. However, because these circumstances applied to INA geese as well as AS geese, those geographic comparisons are still valid.

The general spatial distribution of INA geese and of AS geese overlapped to a relatively large degree. Ely and Dzubin (1994) note no clear distinction between segments of the mid-continent white-fronted goose population during migration, but rather a continuum. However, core distribution areas of INA geese in Alberta and Saskatchewan only marginally overlapped with core distribution areas of AS geese. The consistency of the core distributions of INA geese in Alberta and Saskatchewan over the course of three years may lend these findings some weight, but to make more conclusive statements, sample size of AS white-fronted geese would have to be increased and distributed over multiple years.

Conservation implications

The results presented in this study confirm the importance of several staging grounds for white-fronted geese from Interior Alaska, particularly in east central Alberta and southwest Saskatchewan in Canada, central Kansas and southern Texas in the United States, and northern Tamaulipas and Nuevo Leon in Mexico. Some of these staging grounds have been previously documented (Ely and Dzubin 1994, Yepez Rincon 2004). A distinction of the INA segment of the mid-continent white-fronted goose population based on temporal and spatial segregation may be possible in Alberta and Saskatchewan, particularly in east central Alberta. South of Canada, the results of this study do not

suggest a clear distinction of the INA segment of the mid-continent white-fronted goose population. This suggests that management actions targeted at INA white-fronted geese would be most successful if applied in the Canadian prairies. Currently, hunting seasons open in the beginning of September in north central and part of east central Alberta. If the season opening were delayed until white-fronted geese from other breeding grounds reach these areas, mortality of INA geese could be reduced. Furthermore, these areas in our study were mainly used by INA geese throughout the season. Given that there is a positive correlation between the longitude at which a goose was banded and the longitude of where it was first sighted on fall staging grounds (Ely and Schmutz, 1999), it is not likely that these areas are heavily used by white-fronted geese from the Canadian arctic. Therefore, a reduction in bag limits in the Peace River area and in east central Alberta would likely be even more effective in increasing survival of INA white-fronted geese.

Previous studies based on legband recoveries and neckcollar resightings suggested that the Winchester Lakes area in northern Texas provided an opportunity for management of the INA segment of the mid-continent white-fronted goose population (Ely and Schmutz 1999, Anderson and Haukos 2003). Our study did not show the Winchester Lakes area as a core area for INA white-fronted geese; however, if overlap with mid-continent white-fronted geese from other population segments is small, management actions in this area could nevertheless affect the white-fronted geese from Interior-Northwest Alaska to a relatively large degree.

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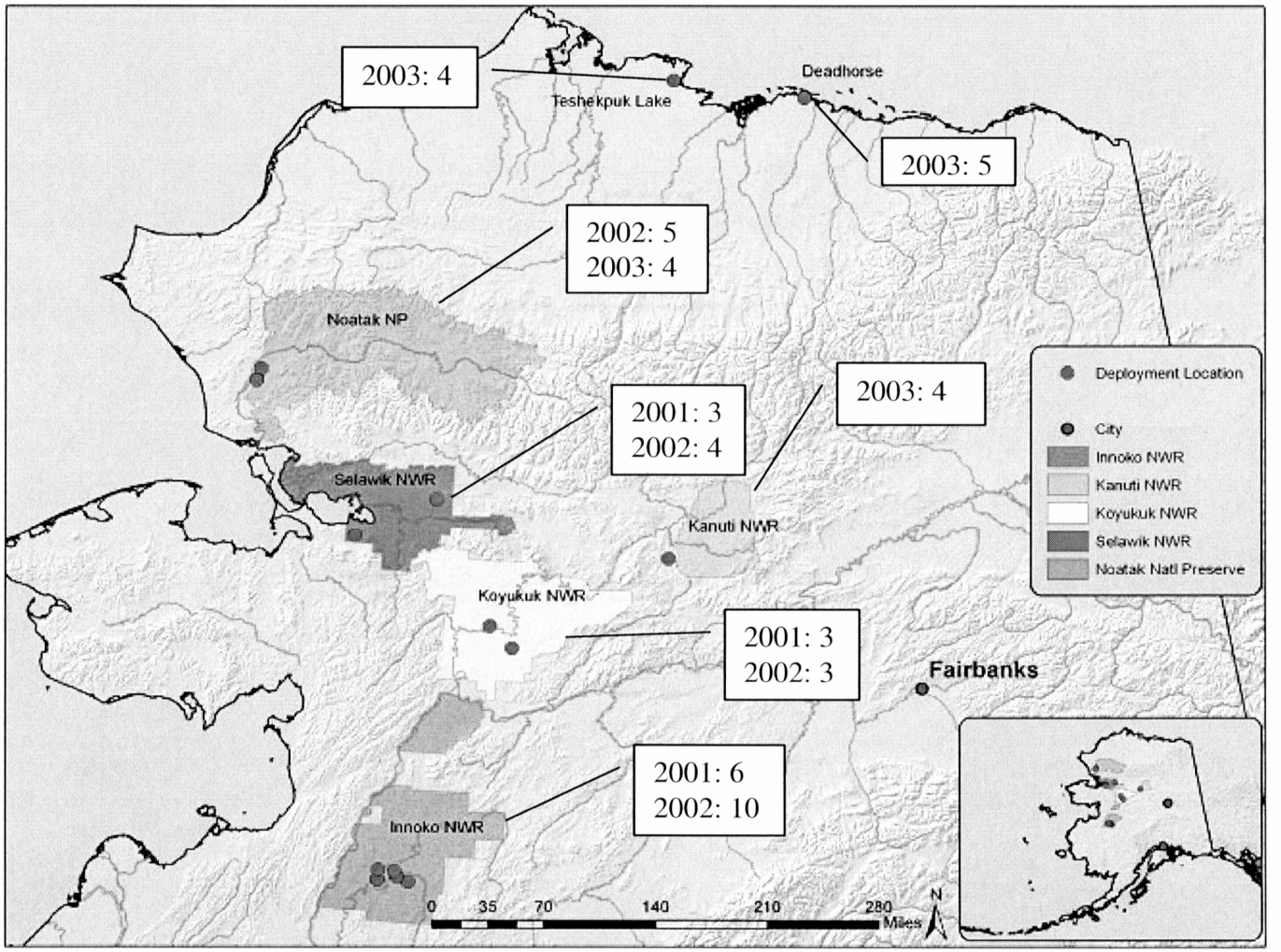

Fig. 1. 1 Capture locations of 51 white-fronted geese *Anser albifrons frontalis* implanted with satellite transmitters in Interior-Northwest Alaska and on the Arctic Slope, Alaska, 2001-2003. NWR = National Wildlife Refuge.

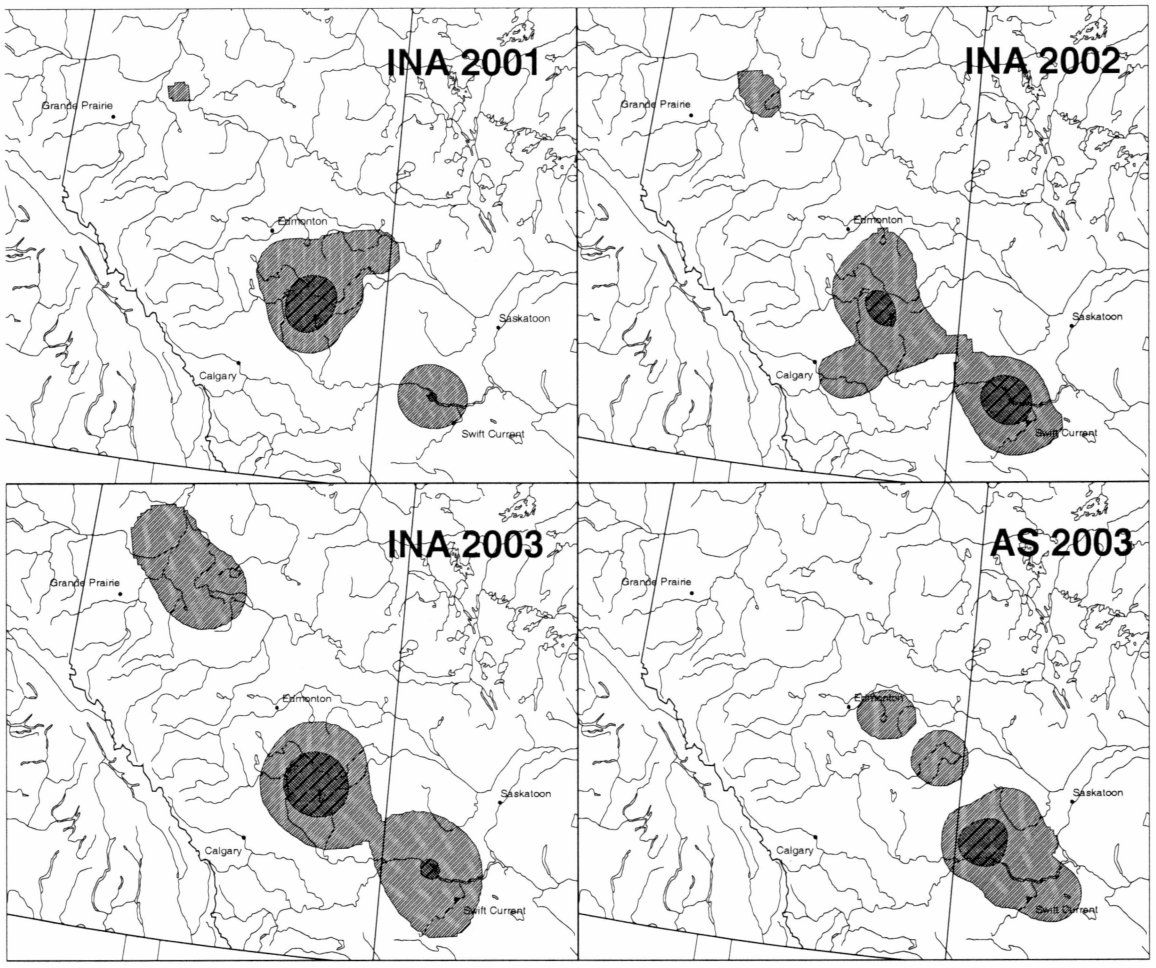

Fig. 1. 2 Fall staging distributions of white-fronted geese from Interior-Northwest Alaska (INA) and white-fronted geese from the Arctic Slope, Alaska (AS) in Alberta and Saskatchewan. 95 % Kernel probability distributions = light shading, 50% kernel probability distributions = dark shading. Data obtained through satellite telemetry. INA 2001: 11 geese, mean = 18 locations per goose, SE = 0.8. INA 2002: 16 geese, mean = 21.2 locations per goose, SE = 1.3. INA 2003: 7 geese, mean = 13.4 locations per goose, SE = 0.5. AS 2003: 9 geese, mean = 9.6 locations per goose, SE = 0.4.

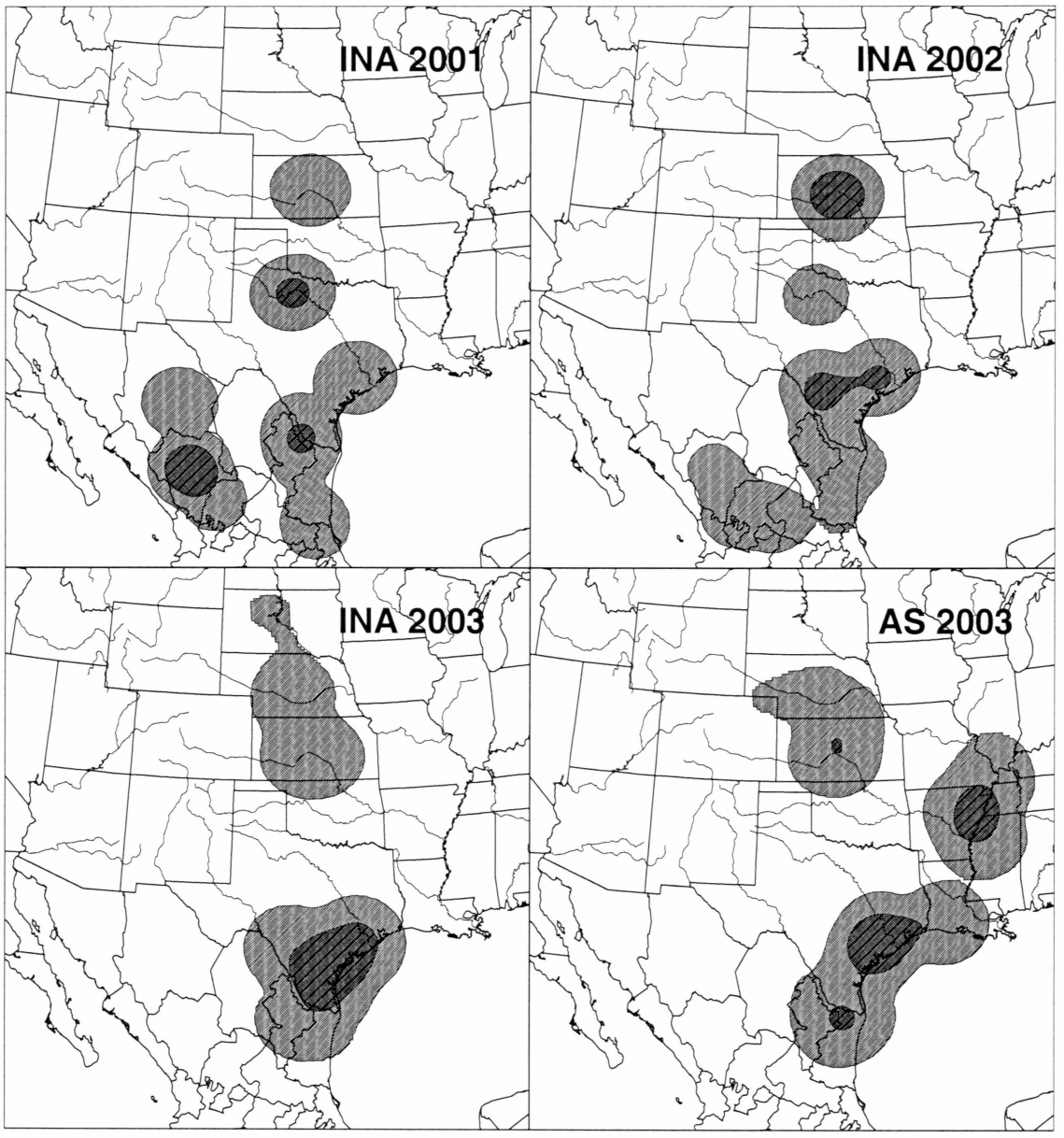

Fig. 1. 3 Winter distributions (south of Canada until 11 February) of white-fronted geese from Interior-Northwest Alaska (INA) and white-fronted geese from the Arctic Slope, Alaska (AS). 95% Kernel probability distributions = light shading, 50% kernel probability distributions = dark shading. Data obtained through satellite telemetry. INA 2001: 11 geese, mean = 31.5 locations per goose, SE = 0.7. INA 2002: 16 geese, mean = 31.5 locations per goose, SE = 0.8. INA 2003: 7 geese, mean = 14 locations per goose, SE = 0.6. AS 2003: 9 geese, mean = 13.9 locations per goose, SE = 0.5.

Table 1. 1 Mean arrival and departure dates and standard error (SE) along migration route of greater white-fronted geese *(Anser albifrons frontalis)* implanted with abdominal satellite transmitters on their molting grounds in Interior-Northwest Alaska and on the Arctic Slope, Alaska, 2001-2003. Because differences among years were not significant data were pooled across years for comparisons between white-fronted geese from Interior Alaska and white-fronted geese from the Arctic Slope.

	Interior Alaska									Arctic Slope, Alaska		
	2001 n=12			2002 n=17			2003 n=8			2003 n=9		
	mean (date)	SE	n	mean (date)	SE	n	mean (date)	SE	n	mean (date)	SE	n
departure from Alaska	25-Aug	1.6	12	25-Aug	1.8	17	23-Aug	2.1	8	3-Sep*	2.0	9
arrival in Alberta/Saskatchewan	29-Aug	1.7	12	29-Aug	1.8	17	26-Aug	1.6	7	10-Sep*	0.9	9
departure from Alberta/Saskatchewan	13-Oct	1.9	11	19-Oct	2.1	16	19-Oct	2.9	7	24-Oct*	1.1	9
arrival at southernmost location	15-Dec	13.5	11	28-Dec	9.4	16	17-Jan	10.0	7	15-Dec	13.5	9

* $p < 0.05$ (Kolmogorov-Smirnov test statistic)

Table 1. 2 Percent overlap between kernel polygons describing the distribution of greater white-fronted geese *(Anser albifrons frontalis)* from Interior-Northwest Alaska and from the Arctic Slope (AS) Alaska, on fall and on winter staging grounds, 2001-2003. Data obtained by satellite telemetry.

	2001/02		2001/03		2002/03		all years		2003/AS	
	95%	50%	95%	50%	95%	50%	95%	50%	95%	50%
Alberta/Saskatchewan	43.7	20.4	34.4	61.5	54.7	20.4	29.2	16.0	26.8	0.4
South of Canada/Winter	55.6	0.0	30.2	2.9	45.1	17.3	27.9	0.0	47.6	24.9

CHAPTER 2. IMMIGRATION AND EMIGRATION OF MID-CONTINENT WHITE-FRONTED GEESE (*ANSER ALBIFRONS FRONTALIS*) ON FALL STAGING GROUNDS IN ALBERTA AND SASKATCHEWAN, CANADA[2]

Abstract: We investigated the hypothesis that white-fronted geese from Interior-Northwest Alaska stage longer in the Canadian prairies in Alberta and Saskatchewan during their fall migration than mid-continent white-fronted geese from Canadian breeding grounds. Corroboration of this hypothesis could imply a higher hunting mortality of white-fronted geese from Interior-Northwest Alaska than from Canadian breeding grounds in the Canadian prairies. We used capture-recapture methods to determine timing and rate at which white-fronted geese from identifiable breeding segments of the mid-continent population arrived on their fall staging areas, and to determine timing and rate at which they departed their staging area in 2001 and 2002. White-fronted geese from Interior-Northwest Alaska arrived earlier in the study area (which included areas in north-central Alberta, east-central Alberta, and south-western Saskatchewan) than white-fronted geese from Canadian breeding grounds. Departure dates from the study area were comparable between white-fronted geese from different breeding locations, therefore indicating that white-fronted geese from Interior-Northwest Alaska did indeed stage longer in the study area than white-fronted geese from Canadian breeding grounds. Because our study area was not equally representative for white-fronted geese from different breeding grounds we caution against making inferences to

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areas in Alberta and Saskatchewan outside our study area. However, we suggest that the temporal segregation of white-fronted geese from different breeding grounds in the study area provides a management tool which could be used to potentially reduce mortality of white-fronted geese from Interior-Northwest Alaska.

Keywords: Alaska, *Anser albifrons frontalis*, apparent survival, emigration, fall staging, immigration, mark-recapture, seniority, white-fronted goose

INTRODUCTION

The mid-continent population of greater white-fronted geese (*Anser albifrons frontalis*) breeds and undergoes primary molt across a wide geographic range, extending from the Seward Peninsula in western Alaska to the western shore of northern Hudson Bay (Bellrose 1980, Ely and Dzubin 1994). Mid-continent greater white-fronted geese can be assigned to different population segments based on nesting areas and migration patterns (Ely and Schmutz 1999). Greater white-fronted geese that breed in Interior-Northwest Alaska (INA) can be distinguished from other segments of the mid-continent population in several ways; they nest mainly in the boreal forest (Spindler et al. 1999), whereas all other segments nest in tundra habitats, and INA white-fronted geese nest and migrate earlier in spring and fall (Ely and Schmutz 1999, Chapter 1).

In the 1990s, evidence from monitoring efforts conducted by Spindler et al. (1999) suggested that numbers of white-fronted geese in some parts in Interior-Northwest Alaska were declining. These concerns gave rise to a study of nesting ecology of white-fronted geese in Interior Alaska (Spindler and Hans 2005) and to an extensive analysis of legband recoveries and neckcollar resightings (Ely and Schmutz 1999). Spindler and

Hans (2005) believed production of INA greater white-fronted geese to be adequate to sustain growth of this segment of the mid-continent population. Banding analysis on the other hand showed that white-fronted geese from Interior-Northwest Alaska had a lower annual survival rate than white-fronted geese from other segments of the mid-continent population in 1990-1994 (Ely and Schmutz 1999).

Mid-continent white-fronted geese accomplish their fall migration mainly in two large steps. During the first step they travel from their breeding grounds to the Canadian prairies in Alberta and Saskatchewan where they stage for up to several weeks, before moving south through the Great Plains to their wintering grounds in Louisiana, Texas, and Mexico (Ely and Dzubin 1994, Chapter 1). Mid-continent white-fronted geese from different breeding grounds aggregate and commingle more during their fall migration while staging in Alberta and Saskatchewan than at any other time of their annual cycle. White-fronted geese are also heavily hunted while staging during fall migration. Between 1992 and 2001, approximately 38% of the white-fronted goose harvest in the Mississippi and Central Flyway occurred in Canada, according to harvest estimates from mail questionnaire surveys (Sharp and Moser, 2001).

Analyses of legband recoveries and results from satellite telemetry showed that white-fronted geese from Interior-Northwest Alaska arrive on their fall staging grounds in the Canadian prairies earlier than white-fronted geese from other breeding grounds (Ely and Schmutz 1999, Chapter 1). The question arises whether INA white-fronted geese stay longer in the Canadian prairies than white-fronted geese from other breeding grounds. Higher hunting mortality as a consequence of longer fall residence time in the

Canadian prairies could lead to lower annual survival rates for INA white-fronted geese versus white-fronted geese from other breeding grounds.

Current knowledge of migration timing of white-fronted geese in the Canadian prairies is based on satellite telemetry (Chapter 1) or banding analysis (Ely and Schmutz 1999). Analysis of satellite telemetry data showed that INA white-fronted geese arrive earlier on their fall staging grounds in the Canadian prairies than white-fronted geese breeding and molting on the Arctic Slope in Alaska (Chapter 1). However, elaborate logistics and high costs limited the sample size of our satellite telemetry study, particularly for geese from the Arctic Slope, and did not allow for inclusion of white-fronted geese from Canadian breeding grounds, which constitute the majority of the population of mid-continent white-fronted geese. Ely and Schmutz (1999) primarily used data from legband recoveries for their analysis which require a bird to be killed and reported to enter the analysis. Thus, these data provided no information on departure time from the study area. Hunting pressure is likely to change throughout the season, which may result in disproportional representation of bird numbers in legband recovery data. Observation of neck collared white-fronted geese corroborated the findings that INA white-fronted geese were earlier to migrate into Alberta and Saskatchewan in the fall than white-fronted geese from other breeding grounds (Ely and Schmutz, 1999). However, results from previous neckcollar resightings likely underrepresented potential differences in migration timing between white-fronted geese from different breeding and molting grounds because neckcollar resighting efforts in the Canadian prairies mainly occurred during dates of highest white-fronted goose density.

More detailed information is needed regarding migration timing of INA white-fronted geese in comparison with white-fronted geese from other breeding grounds in the Canadian prairies during fall migration. Knowledge of potential differences in temporal distribution between white-fronted geese from different breeding grounds could be used to target management actions at segments of the mid-continent white-fronted goose population such as the INA white-fronted geese.

In this study, we attempted to determine the timing and rate at which white-fronted geese from different breeding segments of the mid-continent population arrived (immigration), and the timing and rate at which they departed the staging areas in Alberta and Saskatchewan in 2001 and 2002 (emigration). Our neckcollar resighting efforts were temporally and spatially more extensive than previous efforts. We analysed these resighting data using capture-recapture (CR) techniques. Because detection of marked individuals is always imperfect, CR methods simultaneously estimate detection probability (p) along with the parameters of interest (immigration and emigration). CR methods have frequently been employed to estimate rates of immigration and emigration; Cormack-Jolly-Seber (CJS) models have been used to estimate emigration rates and stopover duration of waterfowl in wintering areas (Pradel et al., 1997) and of passerines in staging areas (Holmgren et al. 1993, Kaiser 1995, Figuerola and Bertolero 1998, Nichols and Kaiser 1999, Kaiser 1999). Rates of immigration into a population have been estimated using a reverse capture history approach (Pradel 1996, Pradel and Lebreton 1999, Nichols et al. 2000).

STUDY AREA

The study area was chosen to optimize resighting probabilities of INA white-fronted geese. Data from previous neckcollar resighting efforts (Kathy Meeres, Canadian Wildlife Service, Saskatoon, Canada, pers. comm.) were used to map the distribution of INA white-fronted geese in Alberta and Saskatchewan. The results showed that during their fall migration, white-fronted geese from Interior Alaska roughly aggregated in 3 clusters in Alberta and Saskatchewan: in north-central Alberta (Peace River), in east central Alberta (Edmonton, Stettler, Hanna, Wainwright), and in south-western Saskatchewan (Kindersley, Rosetown, Swift Current, Saskatoon). The clusters in east central Alberta and in south-western Saskatchewan are part of the Prairie Lands. The Prairie Lands are a mosaic of agricultural lands consisting of row crops and pastures, interspersed with wetlands and native prairie. For a more detailed description of waterfowl habitat see Pederson et al. (1989). The cluster in north-central Alberta entails agricultural lands surrounded by forests of poplar and mixed coniferous trees. The Peace River constitutes its major drainage and, together with several large lakes and wetlands, provides roosting and staging habitat for migrating waterfowl.

METHODS

Collar deployment

Resightings efforts in this study mainly relied on collaring efforts from previous years. Since 1990, the U. S. Fish and Wildlife Service has attached neckcollars to 6,000 white-fronted geese in Interior-Northwest Alaska, with the majority of collars deployed between 1990 and 1994. Geese were collared in several areas within INA including

Innoko, Koyukuk, Selawik, and Kanuti National Wildlife Refuges. The Canadian Wildlife Service conducted neck collaring efforts in the Canadian arctic in various locations between 1987 and 1996. In the Central and Eastern Canadian Arctic (ECA), which included Coppermine, Victoria Island, Kent Peninsula, Queen Maud Gulf and Inglis River, approximately 12,830 neckcollars were deployed, and in the Western Canadian Arctic (WCA), which included the Anderson River Delta and Old Crow flats, approximately 6,000 collars were deployed. During the second year of this study (2002), 228 additional neckcollars were attached to white-fronted geese in Interior-Northwest Alaska.

White-fronted geese in this study were captured during molt in July while flightless. They were driven into capture nets by float planes, helicopters, or people on foot (Lobpries 1980, Alisauskas and Lindberg 2002). The majority of neck collared geese were non-breeding adults. Depending on breeding ground affiliation neckcollars were either red (INA and WCA) or blue (ECA). They displayed a unique engraved three-character alphanumeric code in white, making each goose individually identifiable. For further description of neckcollars see Alisauskas and Lindberg (2002).

Collar resightings

We attempted to cover the entire study area by placing 1 permanent observer in each of the 3 clusters. Because clusters were very large, observers needed more than 1 day to cover an adequate area. However, sampling occasions needed to be short enough to provide sufficient resolution to detect fine-scale temporal changes in arrival and departure patterns. These considerations resulted in a 4-day route, during which observers

visited different places in their cluster known to serve as staging grounds for white-fronted geese. Observers repeated this route with minor deviations for as long as white-fronted geese were present in their cluster. Hence, sampling occasions consisted of 4 days of observations plus 1 additional day which served as a day off. Days off were randomly assigned within sampling occasions. Sampling occasions spanned the same dates in both years of the study.

Observations of geese were made while birds were roosting on waterbodies or while they were feeding in crops. Permanent observers used Questar telescopes to read neckcollars. Temporary observers supported permanent observers. Both permanent and temporary observers recorded time spent observing geese.

Modeling procedures

We combined all neckcollar resightings into 1 dataset containing 6 different groups (breeding ground affiliation x year). For the estimation of immigration and emigration parameters we combined ECA and WCA white-fronted geese because we were mainly interested in potential differences between INA white-fronted geese and white-fronted geese from other breeding grounds, and because sample sizes of ECA and WCA geese were comparably small, particularly in 2002. Preliminary analysis showed that the global CJS-model contained a large number of unidentifiable parameters. Consequently, we collapsed capture histories by combining 2 consecutive sampling occasions, therefore increasing the length of each sampling occasion from 5 to 10. This resulted in a dataset with 9 sampling occasions. By combining sampling occasions we accepted a reduction in our ability to detect fine-scale temporal changes in immigration and emigration rates.

Schaub et al. (2001) developed a method that combined CJS models and the reverse capture history approach to determine stopover length of passerines in staging areas. This approach takes into account the time birds spent at the stopover site after they have been captured as well as the time birds spent at the stopover site before capture. This method has been successfully used in other studies estimating stopover length of passerine birds (Morris et al., 2005). However, the method has recently been criticized for producing estimates which are biased high, because it incorporates an estimation of time spent at the stopover site before capture (Efford 2005, Pradel et al. 2005). In the present study, we initially attempted to apply Schaub et al.'s (2001) method to my data, however, results from this method implied that white-fronted geese in our study area were residents. We concluded that Schaub et al.'s (2001) method may be more appropriate to estimate stopover length of passerine birds which, unlike white-fronted geese, are not subjected to hunting mortality, migrate in pulses through stopover sites, and remain in study areas for relatively short periods of time (<2 weeks).

Instead, we used recruitment analyses (Pradel 1996) to estimate arrival rates (immigration) in the study area (all 3 clusters combined). By reversing the capture histories, recruitment analysis estimates seniority (γ) and resighting rates (p). Seniority (γ) represents the probability that a goose present at a given sampling occasion i was already in the study area during the previous occasion $i-1$. For the purpose of this study we refer to seniority (γ) as immigration or arrival rate. We used Cormack-Jolly-Seber (CJS) models (Lebreton et al. 1992) to estimate departure rates (emigration) from the study area. CJS models estimate apparent survival (ϕ) and resightings rates (p). Apparent

survival (ϕ) represents the probability that a goose present at a given sampling occasion i will still be present during the following sampling occasion $i + 1$. Apparent survival (ϕ) includes the probability that an individual both survives and remains within the study area. Assuming a true survival of 1, $1-\phi$ represents the emigration from the study area. In this study, we are mainly interested in relative comparisons between white-fronted geese from different breeding groups, and hence assume that true survival is merely equal among geese from different breeding groups during the time of observations. For the purpose of this study, we refer to apparent survival (ϕ) as residence probability (Pradel et. al. 1997).

Pradel (1996) has developed methods for the estimation of γ and p only, and for simultaneous estimation of γ, ϕ, and p. Because the global CJS-model displayed a high degree of unidentifiability even after sampling occasions were combined, we decided to model γ and ϕ in 2 separate analyses, hence simplifying the model structure put on the data. However, because this approach ignores the covariance between ϕ and γ, we transferred our final models determined in the separate analyses into an analysis which combined γ and ϕ to obtain more appropriate variance estimates. From the resulting models of the separate ϕ and γ analysis we used all models with a ΔAIC = 0.00 for the combined analysis. If more than 1 model with a ΔAIC = 0.00 resulted from each of the separate ϕ and γ analysis, we used all possible combinations of models for ϕ and γ in the combined analysis. We used model averaging in the combined analysis to calculate real parameter estimates and associated variances.

To check for adequacy of our data to the CJS assumptions, we carried out goodness-of-fit (GOF) tests using program RELEASE within program MARK (White and Burnham, 1999). We considered Test 2 and Test 3 at a significance level of α=0.05.

We used an information-theoretic approach (Lebreton et al. 1992, Burnham and Anderson 1998, Anderson et al. 2000) to measure relative support for my predictions, which we described in a set of a priori defined models. Predefined models were created using a hierarchical approach (Lebreton et al. 1992), modeling the resighting parameter p first, then proceeding to the estimation of γ and ϕ, respectively. The model with the best fit was determined using differences in Akaike's Information Criterion, corrected for finite sample size (ΔAICc; Burnham and Anderson 1998). Akaike's Information Criterion is an estimator of relative Kullback-Leibler information and commonly used in CR studies (Lebreton et al. 1992, Burnham and Anderson 1998). We used program MARK (White and Burnham, 1999) for model selection and to obtain parameter estimates.

A priori models

Resighting parameter (p).— We started with the global model according to which p varied by year, breeding ground affiliation and time within season. We modeled different forms of time dependence first, then applied further constraints to the model with the best fit regarding temporal variation by removing either breeding ground or year effects or both. A within-season-time-effect was modeled as a trend, incorporating the idea that observers would improve in their ability to read neckcollars. In a second within-season-time-effect we categorized sampling occasions as either 'good' or 'bad' according to

environmental influences such as weather conditions. In a third within-season-time-effect we modeled for sampling effort by adding hours observers had spent watching geese as standardized covariates. We considered additive relationships between these variables and groups of geese from different breeding grounds and years as well as interactions. In γ and ϕ, respectively, we retained structure while modeling p. We used the best resulting model of p for the estimation of ϕ and γ.

Immigration (γ).—We predicted that immigration would start at a low rate and increase over time to a value of nearly 1. This means that the probability of an individual goose already have been observed at the previous sampling occasion would grow until no new geese can be detected. We further hypothesized that the rate of immigration and the timing of its end would be different between INA white-fronted geese and white-fronted geese from other breeding grounds. Based on potential interannual variation in migration timing we also hypothesized differences between years. We implemented our predictions by applying a trend to each of the 4 groups (INA 2001, INA 2002, ECA/WCA 2001, ECA/WCA 2002). To determine when immigration would cease (in essence, plateau in value and become constant over time), we constructed 6 models per group with trends of different duration. The longest trend encompassed the first 7 parameter estimates, the shortest trend the first 2 parameter estimates. We assumed an interactive relationship between groups and trend. We determined the model with the best fit for each group in a hierarchical fashion by modeling the 4 groups in the order of the magnitude of their data, starting with the group with the largest sample size. This resulted in the following modeling sequence: INA 2002, INA 2001, ECA/WCA 2001, and ECA/WCA 2002. We

assumed that this order would minimize disparity in power to detect structure for each group. While modeling 1 group, the remaining 3 groups were either kept at a continuous trend or, if they had already been modeled, parameterized according to the previously selected model with the best fit. The a priori model suite for γ further contained the top-model selected in the analysis of p and the global model.

Residence probability (ϕ) – We estimated the residence probability (ϕ) in a almost identical fashion to the immigration rate (γ). However, while we assumed that immigration would start at a low rate followed by an increase, we predicted that residence probability would be near 1 in the beginning, then start to decrease as geese leave the study area. The longest trend in the analysis of ϕ therefore encompassed the last 6 parameter estimates and the shortest trend the last 2 parameter estimates.

RESULTS

Summary statistics

We observed geese between 23 August and 20 November in 2001, and between 23 August and 31 October in 2002. Because geese left the study area earlier in 2002 than in 2001, we did not record any neck collared geese during the last 2 sampling occasions in 2002. Between clusters, there were temporal differences in the presence of white-fronted geese. Collars were first recorded in the 2 clusters in Alberta and then in Saskatchewan. On average, geese departed from north-central Alberta first, then from east central Alberta and lastly from south-western Saskatchewan.

A majority of observed white-fronted geese with neckcollars came from Interior Alaska in both years. In 2002, we recorded considerably fewer ECA white-fronted geese

with neckcollars than in 2001. Numbers were distributed as follows: 2001: INA = 323, ECA = 209, WCA = 96; 2002: INA = 409, ECA = 73, WCA = 58. Geese from Interior Alaska were observed during up to 6 sampling occasions, geese from the Eastern Canadian Arctic during up to 4 and geese from the Western Canadian Arctic during up to 5 sampling occasions. In both years, >50% of INA geese and > 70% of ECA and WCA geese were seen during 1 sampling occasion only. Neck collared INA and WCA white-fronted geese were present during the first sampling occasion in both years, while neck collared ECA white-fronted geese were not recorded before the second sampling occasion.

Goodness-of-fit testing

The results from GOF testing indicated that the CJS-model adequately fit the data, however, data were too sparse for reliable conclusions for ECA and WCA white-fronted geese in 2002. Because we do not know of any GOF tests and adjustments applicable to reverse capture history models, and because the CJS-model fit the data from groups with sufficient sample sizes, we did not perform any further GOF testing or adjustments and proceeded with the analysis.

Model selection

The best supported model for the resighting parameter p in both separate analyses of γ and ϕ varied by time without any breeding ground or year effects. We used this model for all parameterizations of γ and ϕ. The estimation of γ resulted in 9 best-approximating models (all with ΔAIC = 0.00). All 9 models indicated that in 2001, immigration of INA white-fronted geese as well as of ECA/WCA white-fronted geese eventually reached a

plateau in value and became constant over time (Table 2. 1). During the second year of the study in 2002, the lack of any observations of collared geese in November inhibited unique estimation of the last three γ parameters. Thus, data in 2002 could not distinguish among (1) a continuous trend, (2) a leveling out of the immigration rate at the sixth parameter estimate, and (3), a leveling out of the immigration rate at the seventh parameter estimate. Other high-ranking models (≤ 4 ΔAIC values) described different trend functions in ECA/WCA 2001 or ECA/WCA 2002 white-fronted geese. All high-ranking models in the estimation of γ were unable to identify the last resighting parameter p, the confidence interval overlapped 1. The best supported model for ϕ suggested that residence rates were constant before they began to decrease in all groups except INA 2001 white-fronted geese, which displayed a continuous downward trend (Table 2. 2). Models which described different trend functions in ECA/WCA 2002 white-fronted geese ranked considerably lower ($\geq$11.87 ΔAICc).

Parameter estimates

In the simultaneous analysis of γ and ϕ, combinations of γ and ϕ parameterizations resulted in 9 models (9 parameterizations for γ, 1 parameterization for ϕ, Table 2. 3.). We used model averaging to obtain parameter estimates (Fig. 2. 1). In both years, immigration rates of INA white-fronted geese started at a considerably higher level than immigration rates of ECA/WCA white-fronted geese (INA: 2001 95% CI, $0.27 \leq 0.52 \leq 0.75$, 2002 95% CI, $0.25 \leq 0.79 \leq 0.98$; ECA/WCA: 2001 95% CI, $0.01 \leq 0.04 \leq 0.11$, 2002 95% CI, $0.04 \leq 0.07 \leq 0.14$). In 2001, immigration rates increased until mid-October for INA white-fronted geese, and until the end of September for ECA/WCA

white-fronted geese. In 2002, immigration into the study apparently never completely ceased to increase for white-fronted geese from all breeding grounds.

Emigration rates of INA white-fronted geese in 2001 showed a continuous declining trend, while in 2002, departure rates were constant until the end of September and beginning of October, similar to those of ECA/WCA white-fronted geese in 2001 (Fig. 2. 2). In 2002, emigration rates of ECA/WCA white-fronted geese remained at a low constant level (95% CI, $0.51 \leq 0.61 \leq 0.72$) until the second half of October. Emigration rates for the remainder of the season could not be estimated for ECA/WCA white-fronted geese.

DISCUSSION

Differences in immigration and emigration rates

Estimates of immigration in this study suggest that INA white-fronted geese arrived in the study area considerably earlier than white-fronted geese from the Canadian Arctic. At the beginning of the study period, approximately 20 days passed before a ECA/WCA white-fronted goose had the same probability of having been present at the previous sampling occasion as an INA white-fronted goose. INA white-fronted geese are known to migrate and arrive on their fall staging grounds earlier than white-fronted geese from other breeding grounds (Ely and Schmutz, 1999). This can be explained by a comparatively early phenology of the boreal forest versus the tundra. On the one hand, geese in the boreal forest are able to initiate and complete breeding and raising young comparably early. On the other hand, grazing lawns and draw-down lakes in the boreal forest are flooded by mid-August and the vegetation is senescent which may force geese

to depart their breeding and molting areas earlier than geese breeding in the arctic tundra. We observed relatively little difference in departure rates from the study area between INA and ECA/WCA white-fronted geese; departure rates of INA white-fronted geese in both years as well ECA/WCA white-fronted geese in 2001 reached 50% at approximately the same time (mid-October).

Size of study area

Arrival and departure rates estimated in this study never reached 1 and started at a higher rate than 0, respectively. This is partially due to the inability of standard likelihood theory to provide sensible estimates for parameters lying on a boundary (Reboulet et al. 1999). However, it is also likely related to the size of the study area we attempted to cover. The sampling coverage, even though extended and fairly consistent, was unlikely to cover the whole staging area. During a sampling occasion during peak season, all 3 permanent observers combined may have observed approximately 60,000 white-fronted geese, which corresponds to about 10% of the entire mid-continent white-fronted goose population (Dan Nieman, Canadian Wildlife Service, Saskatoon, Canada, pers. comm.). Therefore, we likely observed only a fraction of the population. Results from satellite telemetry (Chapter 1) further showed that most white-fronted geese move to a different staging area at least once while in Alberta and Saskatchewan. These 2 facts likely resulted in a certain degree of transience in our sampling space, some geese may have been seen only briefly en route to their main staging area, which may not have been covered by observers in this study.

Sample sizes

Numbers of geese seen from the Canadian arctic were comparably small, particularly in 2002. Generally, we did not expect to observe as many neck collared white-fronted geese from the Canadian arctic as we did INA white-fronted geese, because neck collaring efforts on white-fronted geese were stopped in Canada longer ago than in INA. However, lower numbers of ECA/WCA white-fronted geese were likely also a function of the selection of the study area which was optimized for resightings of INA white-fronted geese. Previous analysis of data from legband recoveries and neckcollar resightings (Ely and Schmutz, 1999), as well as results from satellite telemetry (Chapter 1) showed that white-fronted geese on their fall staging areas spatially segregate relative to their breeding ground affiliation. Therefore, basing the selection of the study area on previous resightings of white-fronted geese from Interior Alaska probably resulted in unequal resighting probabilities among geese from different breeding grounds. Low numbers of ECA white-fronted geese in 2002 may have been caused by a shift in spatial distribution, for example due to a change in water levels of waterbodies frequently used for roosting in Saskatchewan.

Transience of ECA/WCA white-fronted geese

We believe that ECA/WCA white-fronted geese remained transient in the study area to a larger degree than INA white-fronted geese. Immigration rates of ECA/WCA white-fronted geese in the study area remained below immigration rates of INA white-fronted geese, and emigration rates of ECA/WCA white-fronted geese, even when constant, were higher than emigration rates of INA white-fronted geese. This suggests that ECA/WCA

white-fronted geese never ceased to arrive into and depart from the study area during our study period. This is likely a consequence of the selection of the study area which was optimized for resightings of INA white-fronted geese as mentioned above.

Assumptions of mortality

Another critical point in this study is the assumption that true survival equals 1 or is equal among white-fronted geese from different breeding grounds during the time of observations. To assess the magnitude of a potential bias to our estimate of emigration we calculated 3-month survival rates from annual survival rates obtained from analysis of data from legband recoveries (Hines et al. 2002) for INA white-fronted geese (0.628) and for ECA white-fronted geese (0.705). The resulting values were 0.890 for INA white-fronted geese and 0.916 for ECA white-fronted geese. This indicates that we could expect a relatively low rate of mortality for the duration of the study. Also, the difference in mortality between INA white-fronted geese and ECA/WCA white-fronted geese was relatively small over a 3-month span compared to the annual rates.

The most obvious source of mortality for white-fronted geese in our study area is hunter harvest. Given that there is likely spatial segregation of white-fronted geese from different breeding grounds during fall staging in Alberta and Saskatchewan (Ely and Schmutz 1999, Chapter 1), differential hunting mortality between white-fronted geese from different breeding grounds may result if hunting pressure were distributed unequally across the staging grounds. There is no information available describing distribution of hunting pressure in relation to number of white-fronted geese present. However, a comparison of kernel analyses performed on location data from satellite telemetry

(Chapter 1) and of kernel analyses performed on data from legband recoveries (Craig Ely, USGS Anchorage, pers. comm.) showed a large degree of overlap for both INA white-fronted geese and for geese from the Arctic Slope, Alaska. This suggests that hunting pressure per capita (goose) may have been equally distributed across the study area.

Several studies suggest that there are physiological or behavioral characteristics in geese which make them more or less vulnerable to hunting mortality (Zicus 1981, Hill et al. 2003). For example, geese in smaller flocks may be more likely to be harvested (Simpson and Jarvis 1979, Lindberg and Malecki 1994). To my knowledge, no corresponding information is available for white-fronted geese. Flock sizes in Alberta generally seemed smaller than flock sizes in Saskatchewan. Analysis of data from legband recoveries (Ely and Schmutz, 1999) as well as results from satellite telemetry (Chapter 1) implied that INA white-fronted geese stage more often in Alberta than white-fronted geese from other breeding grounds. This could indicate a relationship between flock size and hunting mortality of INA white-fronted geese in the Canadian prairies, however, more data are needed to make more conclusive statements.

Influence of neckcollars

Another source of mortality for white-fronted geese in this study are the neckcollars themselves. Alisauskas and Lindberg (2002) showed that neckcollars significantly lower survival of white-fronted geese, and discouraged the use of neckcollars in CR studies. However, in this study such a bias likely affected white-fronted geese from different breeding grounds equally and should therefore be negligible when considering my results.

Conclusions

In this study we only sampled part of the staging area used by white-fronted geese in Alberta and Saskatchewan. Because there are differences in spatial distribution of white-fronted geese from different breeding grounds in Alberta and Saskatchewan (Ely and Schmutz 1999, Chapter 1), inferences can only be made for the study area and not for the staging area as a whole. However, the prevalence of INA white-fronted geese in the study area and the temporal segregation of white-fronted geese from different breeding grounds within the study area stress the importance of the study area for INA white-fronted geese within the Canadian prairies.

It might have been useful to more closely examine the geographic component in our data, for example by modeling immigration and emigration separately for each cluster to assess the importance of each cluster as a staging area for white-fronted geese from different breeding grounds. Ely and Schmutz (1999) suggested that there is spatial segregation on staging areas in mid-continent white-fronted geese depending on where a goose was banded. However, sample sizes in this study were not sufficient to include a spatial component in my analysis.

MANAGEMENT IMPLICATIONS

Results from this study suggest that white-fronted geese from Interior-Northwest Alaska did indeed stage longer in the study area than white-fronted geese from Canadian breeding grounds. These differences are primarily due to an earlier arrival of INA white-fronted geese in the study area. In 2001 and 2002, hunting seasons opened in the study area between 1 September and 10 September. For at least 2 weeks after season opening, a

vast majority of white-fronted geese present in the study area were from Interior Alaska. This could provide an opportunity for managers to differentially influence the population of INA white-fronted geese. For example, if harvest regulations were to be more conservative in the study area in the beginning of the hunting season (lower bag limit, late season opening), these actions would likely most affect INA white-fronted geese.

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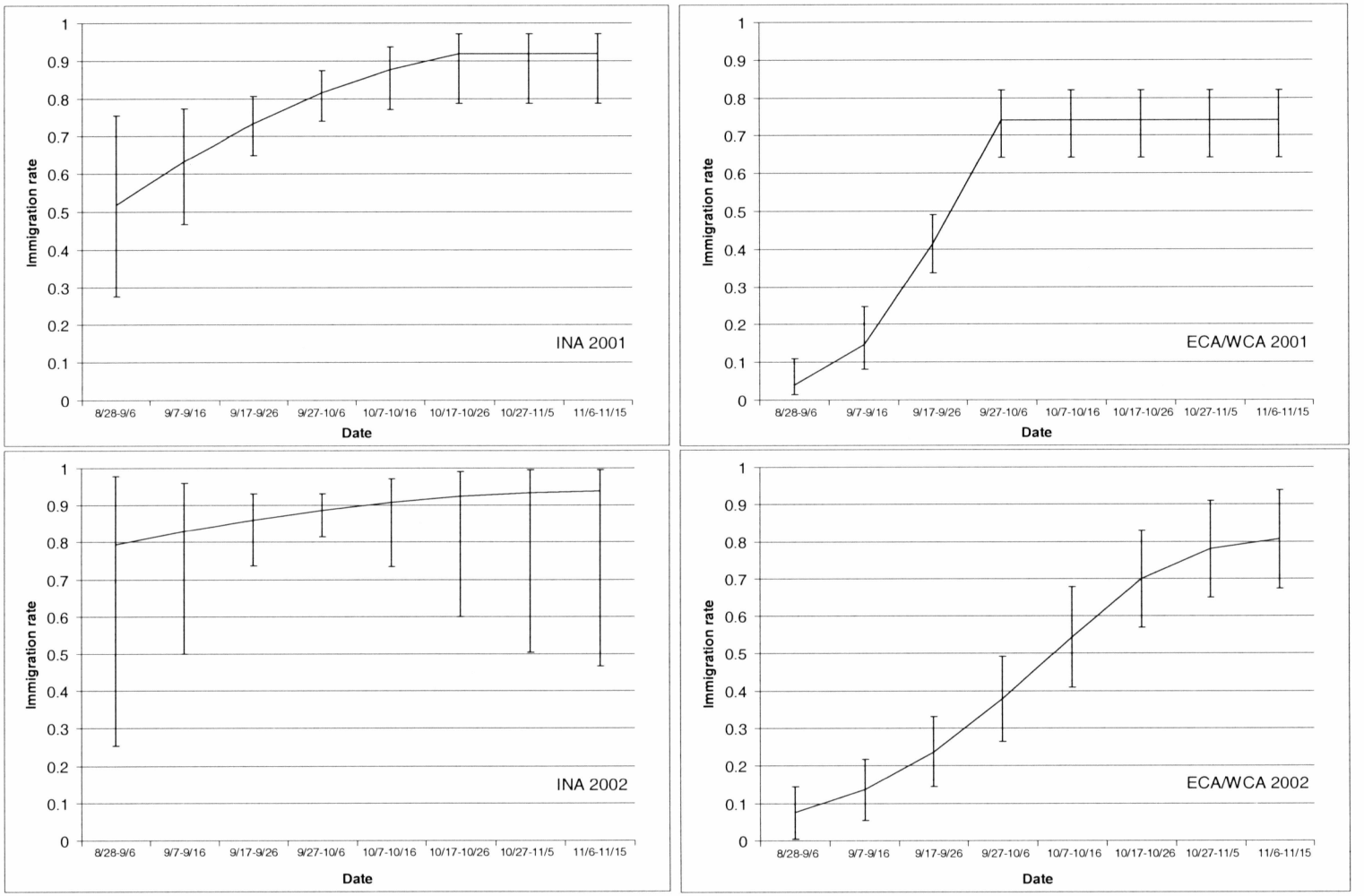

Fig. 2. 1 Immigration rates (γ) of white-fronted geese from Interior Northwest Alaska (INA) and the Canadian Arctic (ECA/WCA) into Alberta and Saskatchewan during their fall migration in 2001 and 2002. Estimates were calculated by averaging the best-approximating models of γ and ϕ which include different trend functions for geese from different breeding grounds and for different years. Error bars indicate 95% confidence intervals.

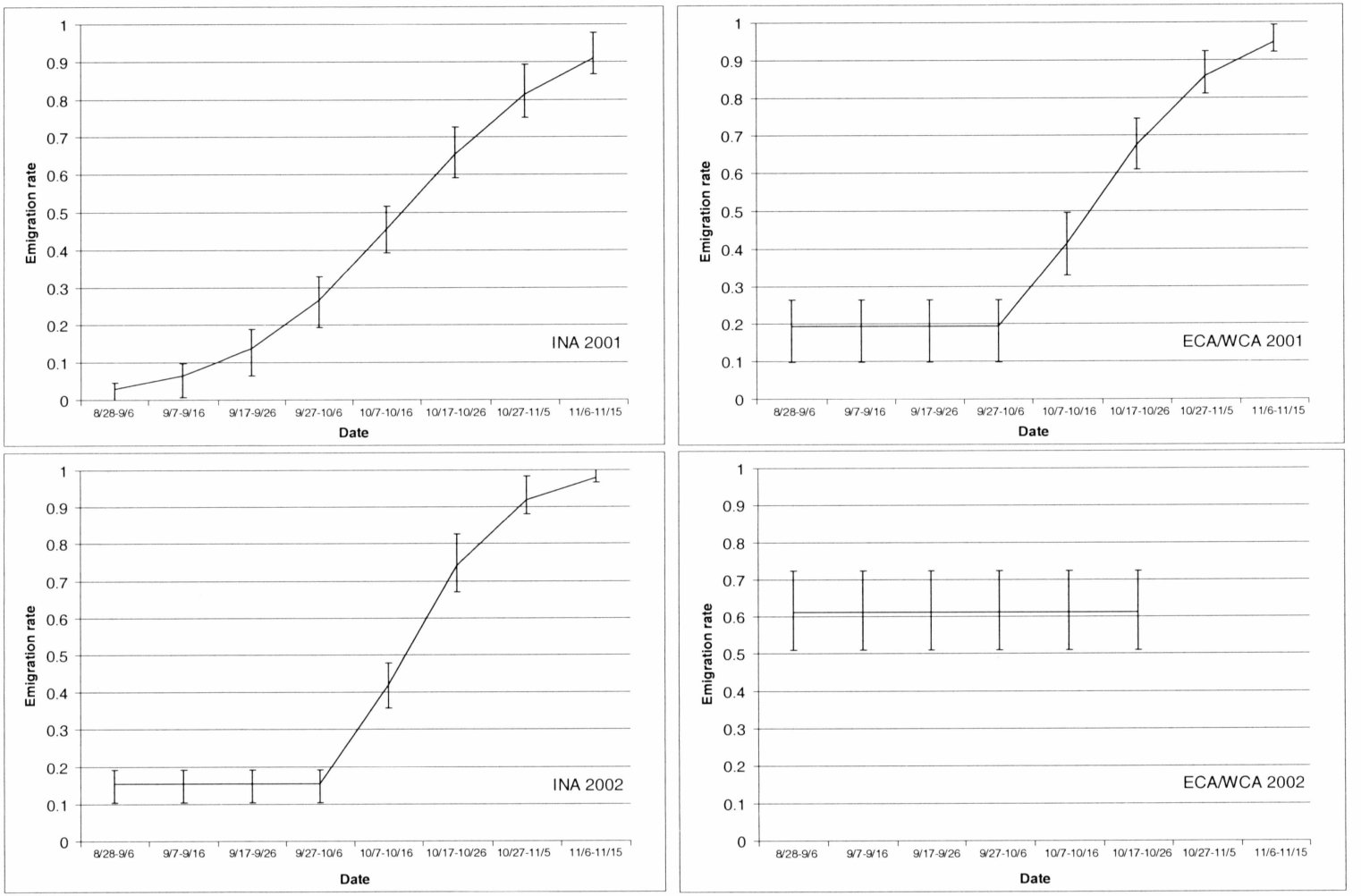

Fig. 2. 2 Emigration rates (1-ϕ) of white-fronted geese from Interior Northwest Alaska (INA) and the Canadian Arctic (ECA/WCA) from Alberta and Saskatchewan during their fall migration in 2001and 2002. Estimates were calculated by averaging the best-approximating models of γ and ϕ which include different trend functions for geese from different breeding grounds and for different years. Error bars indicate 95% confidence intervals.

Table 2. 1 Models with lowest six ΔAICc values and global model used in estimation of immigration rate (γ) of mid-continent white-fronted geese from different breeding grounds during fall migration of 2001 and 2002 in Alberta and Saskatchewan.

Model structure						
p	γ				ΔAIC*c*	$K^c_{estimated}$
	INA[a] 2001	INA 2002	ECA/WCA[b] 2001	ECA/WCA 2002		
time	T_{1-6}	T_{1-6}[d] or T_{1-7} or $T_{continuous}$	T_{1-4}	T_{1-6} or T_{1-7} or $T_{continuous}$	0.00	15
time	T_{1-6}	T_{1-6} or T_{1-7} or $T_{continuous}$	T_{1-3}	$T_{continuous}$	3.15	15
time	T_{1-6}	T_{1-6} or T_{1-7} or $T_{continuous}$	T_{1-6}	$T_{continuous}$	3.30	15
time	T_{1-6}	T_{1-6} or T_{1-7} or $T_{continuous}$	T_{1-5}	$T_{continuous}$	3.32	15
time	T_{1-6}	T_{1-6} or T_{1-7} or $T_{continuous}$	T_{1-7}	$T_{continuous}$	3.60	15
time	T_{1-6}	T_{1-6}or T_{1-7} or $T_{continuous}$	T_{1-7}	T_{1-5}	3.80	15
bg*year*time[e]	bg*year*time				11.66	47

[a] white-fronted geese breeding in Interior-Northwest Alaska
[b] white-fronted geese breeding in the Eastern, Central, or Western Canadian Arctic
[c] "K" denotes numbers of parameters.
[d] "T" denotes a trend, the subscript denotes the duration of the trend in parameter estimates.
[e] "bg" denotes breeding ground affiliation (INA, ECA, or WCA), "*" denotes an interactive relationship between variables.

Table 2. 2 Models with lowest six ΔAICc values and global model used in estimation of residence rate (ϕ) of mid-continent white-fronted geese from different breeding grounds during fall migration of 2001 and 2002 in Alberta and Saskatchewan.

Model structure					ΔAICc	$K^c_{estimated}$
p	ϕ					
	INA[a] 2001	INA 2002	ECA/WCA[b] 2001	ECA/WCA 2002		
time	$T_{continuous}$	T_{4-8}	T_{4-8}	T_{6-8}	0.00	14
time	$T_{continuous}$	T_{4-8}	T_{4-8}	T_{5-8}	11.87	15
time	$T_{continuous}$	T_{4-8}	T_{4-8}	T_{4-8}	12.60	15
time	$T_{continuous}$	T_{4-8}	T_{4-8}	T_{3-8}	13.81	15
time	$T_{continuous}$	T_{4-8}	T_{4-8}	T_{2-8}	14.59	15
bg*year*time[e]	**time**				14.75	15
bg*year*time[e]	bg*year*time				21.80	54

[a] white-fronted geese breeding in Interior-Northwest Alaska
[b] white-fronted geese breeding in the Eastern, Central, or Western Canadian Arctic
[c] "K" denotes numbers of parameters.
[d] "T" denotes a trend, the subscript denotes the duration of the trend in parameter estimates.
[e] "bg" denotes breeding ground affiliation (INA, ECA, or WCA), "*" denotes an interactive relationship between variables.

Table 2. 3 Models used in model averaging to determine parameter estimates in combined estimation of immigration rate (γ) and of residence probability (ϕ) of mid-continent white-fronted geese from different breeding grounds during fall migration of 2001 and 2002 in Alberta and Saskatchewan.

Model structure										
	γ				ϕ				ΔAIC*c*	$K^c_{estimated}$
p	INA[a] 2001	INA 2002	ECA/WCA[b] 2001	ECA/WCA 2002	INA 2001	INA 2002	ECA/WCA 2001	ECA/WCA 2002		
time	$T_{1\text{-}6}$	$T_{cont.}$	$T_{1\text{-}5}$	$T_{cont.}$	$T_{cont.}$	$T_{5\text{-}8}$	$T_{5\text{-}8}$	$T_{7\text{-}8}$	0.0000	23
time	$T_{1\text{-}6}$	$T_{cont.}$	$T_{1\text{-}5}$	$T_{1\text{-}6}$	$T_{cont.}$	$T_{5\text{-}8}$	$T_{5\text{-}8}$	$T_{7\text{-}8}$	0.0000	23
time	$T_{1\text{-}6}$	$T_{cont.}$	$T_{1\text{-}5}$	$T_{1\text{-}7}$	$T_{cont.}$	$T_{5\text{-}8}$	$T_{5\text{-}8}$	$T_{7\text{-}8}$	0.0003	23
time	$T_{1\text{-}6}$	$T_{1\text{-}7}$	$T_{1\text{-}5}$	$T_{1\text{-}7.}$	$T_{cont.}$	$T_{5\text{-}8}$	$T_{5\text{-}8}$	$T_{7\text{-}8}$	0.0033	23
time	$T_{1\text{-}6}$	$T_{1\text{-}7}$	$T_{1\text{-}5}$	$T_{1\text{-}6}$	$T_{cont.}$	$T_{5\text{-}8}$	$T_{5\text{-}8}$	$T_{7\text{-}8}$	0.0033	23
time	$T_{1\text{-}6}$	$T_{1\text{-}7}$	$T_{1\text{-}5}$	$T_{cont.}$	$T_{cont.}$	$T_{5\text{-}8}$	$T_{5\text{-}8}$	$T_{7\text{-}8}$	0.0034	23
time	$T_{1\text{-}6}$	$T_{1\text{-}6}$	$T_{1\text{-}5}$	$T_{cont.}$	$T_{cont.}$	$T_{5\text{-}8}$	$T_{5\text{-}8}$	$T_{7\text{-}8}$	0.1274	23
time	$T_{1\text{-}6}$	$T_{1\text{-}6}$	$T_{1\text{-}5}$	$T_{1\text{-}7}$	$T_{cont.}$	$T_{5\text{-}8}$	$T_{5\text{-}8}$	$T_{7\text{-}8}$	0.1274	23
time	$T_{1\text{-}6}$	$T_{1\text{-}6}$	$T_{1\text{-}5}$	$T_{1\text{-}6}$	$T_{cont.}$	$T_{5\text{-}8}$	$T_{5\text{-}8}$	$T_{7\text{-}8}$	0.1275	23
time	$T_{cont.}$	$T_{cont.}$	$T_{cont.}$	$T_{cont.}$	$T_{cont.}$	$T_{cont.}$	$T_{cont.}$	$T_{cont.}$	17.7054	25

[a] white-fronted geese breeding in Interior-Northwest Alaska

[b] white-fronted geese breeding in the Eastern, Central, or Western Canadian Arctic

[c] "K" denotes numbers of parameters.

[d] "T" denotes a trend, the subscript denotes the duration of the trend in parameter estimates, "cont." denotes continuous trend

[e] "bg" denotes breeding ground affiliation (INA, ECA, or WCA), "*" denotes an interactive relationship between variables.

CONCLUSIONS

This study attempted to spatially and temporally differentiate mid-continent white-fronted geese breeding and molting in Interior-Northwest Alaska from mid-continent white-fronted geese from other breeding grounds. Both satellite telemetry and neckcollar resightings suggested that white-fronted geese from Interior-Northwest Alaska arrive on fall staging grounds in the Canadian prairies in Alberta and Saskatchewan earlier than white-fronted geese from other breeding grounds. Using satellite telemetry, we observed a difference of approximately two weeks in arrival date between white-fronted geese from Interior-Northwest Alaska and white-fronted geese from the Arctic Slope, Alaska. In the neckcollar resightings study, approximately 20 days passed before a white-fronted goose from the Canadian arctic had the same probability of being present at the previous sampling occasion as a white-fronted goose from Interior Alaska.

My observations of an earlier migration of Interior-Northwest Alaska white-fronted geese compared to white-fronted geese from other breeding grounds are consistent with findings obtained through analysis of legband recovery data (Ely and Schmutz, 1999). Earlier migration of Interior-Northwest Alaska white-fronted geese can be explained with the earlier phenology of the boreal forest compared to the arctic tundra. On the one hand, geese in the boreal forest are able to initiate and complete breeding and raising young comparably early. On the other hand, grazing lawns and draw-down lakes in the boreal forest are flooded by mid-August and the vegetation senescent (Mike Spindler, pers. comm.) which may force geese to depart their breeding and molting areas earlier than geese breeding in the arctic tundra.

Results regarding departure rates from the Canadian prairies were more diverse: Departure rates obtained from neckcollar resighting data differed relatively little between Interior Alaska white-fronted geese and white-fronted geese from the Canadian Arctic. Results from satellite telemetry indicated that white-fronted geese from the Arctic Slope, Alaska, left the Canadian prairies approximately a week later than white-fronted geese from Interior Alaska. These different results are likely due to differences in methodology. Satellite telemetry in this study allowed us to detect temporal differences on fall staging grounds on a finer scale than did modeling neckcollar resightings. Further, the sampling space was different between the two methods: Satellite telemetry provided continuous tracking of an individual, while neckcollar resightings only took place in part of the staging area used by white-fronted geese in Alberta and Saskatchewan.

During the second portion of migration south of Canada and on wintering grounds I did not detect any temporal differences between Interior Alaska white-fronted geese and geese from the Arctic Slope, Alaska. However, the small sample size in combination with the high degree of variability among individuals likely did not provide enough power to detect potential differences.

Within white-fronted geese from Interior Alaska I did not observe any temporal differences in migration timing among the three years of the study. Migration of both Interior Alaska white-fronted geese and geese from the Arctic Slope was synchronized during the first portion of their migration to the Canadian prairies, but showed a high degree of individual variability during the second portion of migration south of Canada and on wintering grounds. Similarly, white-fronted geese from Interior Alaska were

spatially rather consistent among years during fall staging in the Canadian prairies, but were widespread and individually highly variable south of Canada on wintering grounds. During fall staging they consistently used areas in north central and in east central Alberta and in southwest Saskatchewan. During the remainder of the fall migration and during winter they variously used areas in central Kansas, coastal Texas, and Tamaulipas and Nuevo Leon in Mexico. Areas in the Mexican highlands and in northern Texas were part of the distribution in 2001 and in 2002, but not 2003. Conversely, in 2003, areas in Nebraska and South Dakota were part of the distribution, but not so in 2001 and 2002. Across all years combined, core use areas on wintering grounds did not overlap at all.

Between white-fronted geese from Interior Alaska and white-fronted geese from the Arctic Slope, Alaska, areas of use differed more on fall staging grounds in the Canadian prairies than on wintering grounds, even though the general spatial distribution of white-fronted geese from Interior Alaska and of white-fronted geese from the Arctic Slope overlapped to a relatively large degree. Ely and Dzubin (1994) noted no clear distinction between segments of the mid-continent white-fronted goose population during migration, but rather a continuum. However, areas of core use of Interior Alaska white-fronted geese the Canadian prairies only marginally overlapped in Saskatchewan with core use areas of geese from the Arctic Slope (<0.4%). South of Canada and on wintering grounds, core use areas of Interior Alaska geese and Arctic Slope geese overlapped to almost 25%.

The results of this study showed that (1) spatial and temporal distribution of Interior Alaska white-fronted geese was most consistent in the Canadian prairies in Alberta and

Saskatchewan, (2) spatial and temporal distribution between Interior Alaska white-fronted geese and geese from the Arctic Slope, Alaska, varied most in the Canadian prairies in Alberta and Saskatchewan, and (3) timing of arrival but not of departure differed between Interior Alaska white-fronted geese and white-fronted geese from the Canadian arctic.

Therefore, management actions targeted at Interior Alaska white-fronted geese should be applied in the Canadian prairies, particularly in Alberta. Such a management action could be to alter the season opening date. A delay in season opening might increase survival if hunting mortality is additive with non-hunting mortality. If this change in survival is not coupled with a density-dependent change in reproductive performance, it may lead to an increase in the size of the Interior Alaska segment of the mid-continent white-fronted goose population.

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